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SPONTANEOUS VARIABILITY OF BLOOD PRESSURE IN PATIENTS WITH HYPERTENSION: RESULTS OF LONG-TERM TELEMETRIC BLOOD-PRESSURE MEASUREMENTS

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16. Abstract The method of microcatheter blood pressure telemetry permits deeper insights into spontaneous variability in ordinary blood pressure. In long-term measurements on 77 unselected hypertensives, the well-known circadian and diurnal rhythms of blood pressure were detected. The patterns have the same form but occurred at different levels in the three WHO categories of hypertonia. Exercise and stress caused considerable modifications in the profile. Regularities were observed in time of day and reaction to exercise.

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SPONTANEOUS VARIABILITY OF BLOOD PRESSURE IN PATIENTS WITH HYPERTENSION: RESULTS OF LONG-TERM TELEMETRIC BLOOD-PRESSURE MEASUREMENTS

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Arterial blood pressure in human beings is a controlled va- /1225*
riable, controlled essentially by the ratio of cardiac output to total peripheral vascular resistance. In turn, cardiac output and vascular resistance depend on a number of psychological, nervous, humoral, and organic factors. The interplay of these factors will decide whether there will be intact regulation in the normal range -- as in persons with healthy blood pressure -- or disturbed regulation in the excessively high range -- as in hypertensives. The disturbance of circulatory regulation is also expressed by enhanced fluctuations in the blood pressure after resting (v. Uexküll, 1964, Richardson et al., 1964). Probably, hyper-reactivity of central blood-pressure-raising areas are responsible for this effect (v. Eiff, 1967).

Apart from these rather short-term "situational" blood-pressure fluctuations, time of day also influences the resting blood profile of both healthy persons and hypertensives. In particular, studies with automated indirect measurements (Bock et al., 1965; Zülch et al., 1967) showed that resting blood pressure follows a two-phase rhythm with minima around noon and midnight as well as maxima in the morning and evening. A blood pressure measured at a particular time should just be considered a record of a single moment, and the clues it provides regarding the overall blood-pressure situation of the individual are greatly restricted by this spontaneous variability.

* Numbers in the margin indicate pagination in the foreign text.

Method

We have not yet mentioned those changes in blood pressure which occur as the result of simple everyday loads, and as such cause a "reality-oriented" modification of the resting blood pressure profile. However, there are methodological difficulties in detecting these changes, which are so important in assessing everyday circulatory loads. Indirect measurement by the Riva-Rocci method with an inflatable cuff and auscultation of the Korotkoff noises yields reliable results only with resting subjects; blood pressure cannot be measured satisfactory when the subject is under physical stress -- even a slight one.

Therefore, we have followed Bachmann et al. (1967) and Bevan et al. (1969) and developed a simple procedure -- microcatheter blood pressure telemetry (Krönig et al., 1972) -- which makes it possible to measure, continuously over periods up to several days, the intraarterial blood pressure of freely moving subjects. The apparatus carried by the subject -- countercirculation infusion, modulator, and telemetry transmitter -- is housed in a briefcase; pressure is recorded by a miniaturized pressure pickup attached to the upper arm and connected to an indwelling plastic cannula in the /1226 Arteria brachialis.

In order to be able to make comparisons of our measurements both for a single individual and from one patient to the next, we set up so-called "normalized periods" at various times five times a day in all our long-term telemetric blood pressure measurements; such a "normalized period", as a reproducible indicator of everyday loads, consists of 20 min lying down, 10 min standing, 10 min walking, climbing two stories of stairs once, and again 20 min lying down. As shown by the example of sections from an original curve (Fig. 1) of a long-term telemetric blood pressure measurement of a 43-year-old female patient with essential hypertonia,

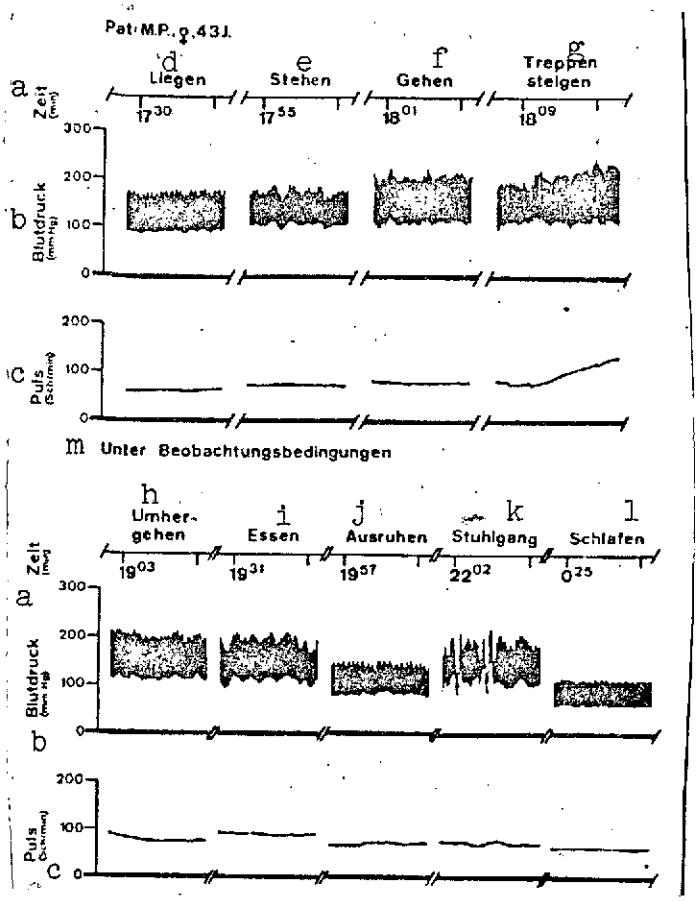

Fig. 1. Sections of a long-term telemetric blood pressure measurement of a 43-year-old female patient with essential hypertonia; upper half of picture under observation conditions, lower half of picture under general steady conditions.

Key: a. Time; b. Blood pressure; c. Pulse (Sch. = beats); d. Lying down; e. Standing; f. Walking; g. Climbing stairs; h. Walking around; i. Eating; j. Resting; k. Defecating; l. Sleeping; m. Under observation conditions
J = years

the blood pressures rises under observation conditions within a "normalized period" encompass those fluctuations occurring in everyday activities.

Results and Discussion

Even though there are considerable individual differences in the pattern of hypertensive reactions to everyday loads and even one and the same patient can react differently to the same load at different times of day, we have attempted to average some of our results for 77 unselected hypertensives, ordered by degree of severity in accordance with the WHO stages. The breakdown of the patient pool is shown in Fig. 2; as expected, the WHO Stage II group was the largest. The well-known two-phase day/night rhythm of resting blood pressure was found in all three groups (Fig. 3). By comparison with the sleep minima or the sleep averages, the midday values were only slightly below the morning and evening values. For uniformity, the resting values

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WHO-I	11	9	2	45,2 J.	31-58 J.
WHO-II	50	31	19	47,6 J.	21-71 J.
WHO-III	16	7	9	48,3 J.	26-63 J.
cGesamt	77	47	30	47,4 J.	21-71 J.

Fig. 2. Patient pool subjected to telemetric blood pressure measurement continuously for at least 24 hours.

Key: a. Mean age; b. Range; c. Total
J. = years

during the day were recorded as so-called "relaxation blood pressures" following exercise in the form of climbing stairs; comparison studies on another group of patients showed that this value is close to the basic blood pressure of Smirk (Krönig et al., 1973). As the diagram (Fig. 3) shows, the mean values of the WHO I patient group were altogether normotonic under these conditions or just in the transition region to "borderline hypertension", which is quite consistent with the studies of Julius and Conway (1967). Also, in the patients of WHO Stage II, the sleep minima were still in the normal range, while the sleep averages just suggested the existence of arterial hypertonia. In our opinion, these frequently normal blood pressures during sleep mean that there should be particularly strict requirements for prescribing a short-acting antihypertensive for the evening. Only in the WHO Stage III group were even the lowest values during sleep clearly hypertonic.

The modification of this resting blood pressure profile due /1227
to reactions to everyday exercise such as standing, walking, and climbing stairs is considerable in all three stages, and varies -- if only slightly -- with time of day. Relative to the preceding resting value recorded while lying down (Fig. 4), the systolic pressure increment (ΔP) during stair climbing is somewhat larger in all three stages at noon and in the evening than in the morning; less strenuous exercise such as walking produces this effect only in patients of Stages I and II. The diurnal rhythm of resting

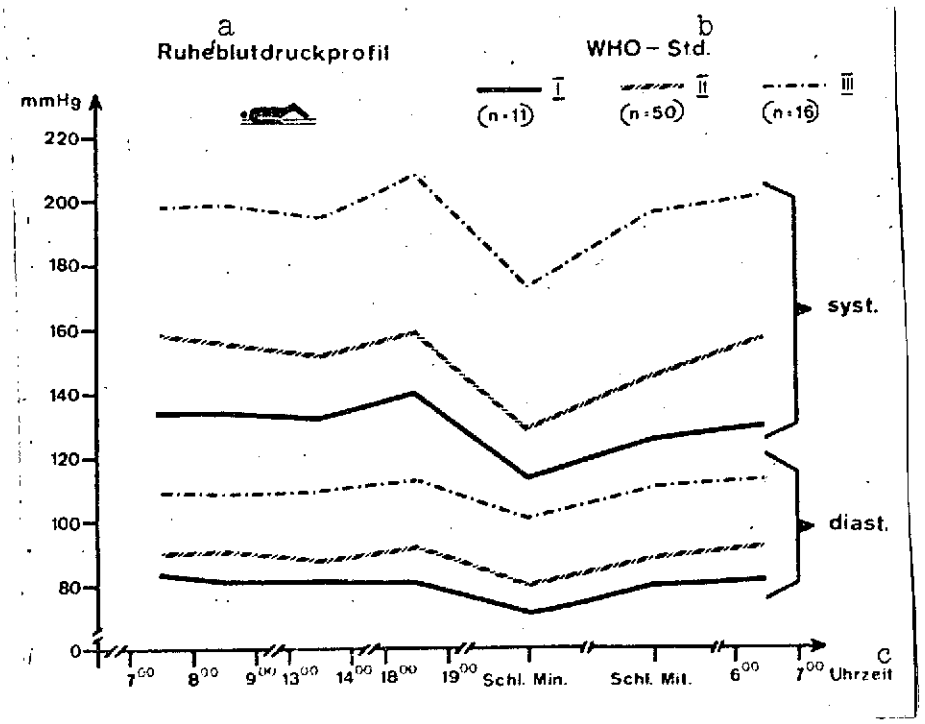

Fig. 3. Mean values of systolic and diastolic blood pressure for our patients in WHO Stages I, II, and III at different times of day while lying down (relaxation after exercise in the form of climbing stairs) and during sleep (Schl. Min. = minimum blood pressure in sleep: Schl. Mit. = = average blood pressure in sleep).

Key: a. Resting blood pressure profile
b. Stage
c. Time of day

blood pressure implies that the largest absolute increment due to exercise in the form of stair climbing is usually found in the middle of the day, while the maximum blood pressures in response to everyday loads occur in the evening hours. It may be that this is related to the peak in athletic performance in the evening hours observed by sports doctors (Voegt et al., 1968), but we still do not know for sure. A conspicuous feature is the behavior of systolic blood pressure during orthostatic activity: while in hypertonia stage I, all subjects exhibited an average rise over the resting value toward the evening, the systolic orthostatic values were below the resting blood pressure level in patients of WHO Stage II in the morning and in patients of WHO Stage III both

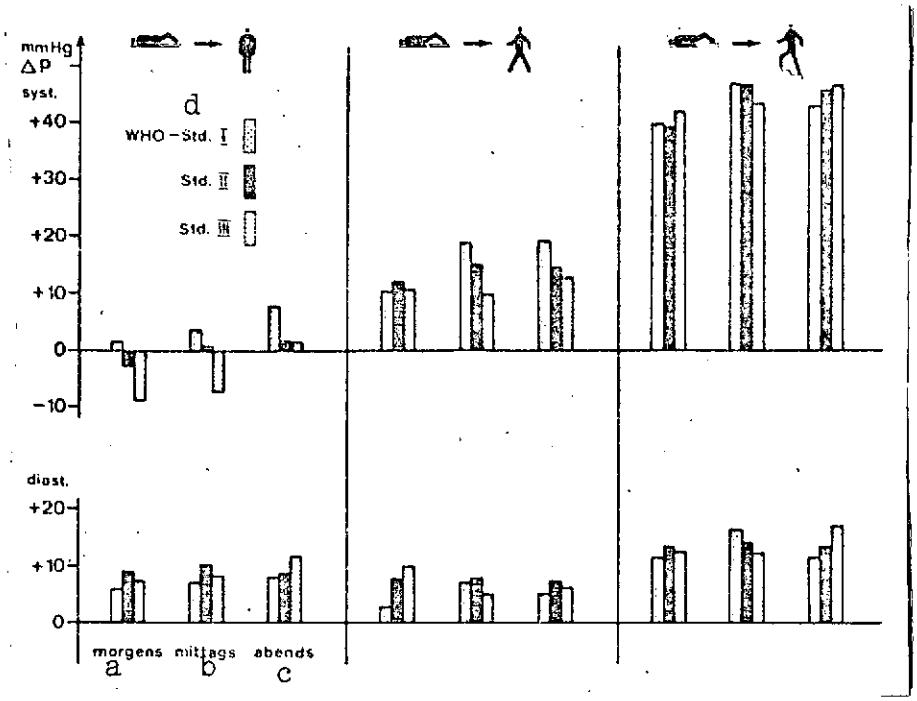

Fig. 4. Mean values of systolic and diastolic blood pressure increments (ΔP) in everyday exercise at different times of day in the three patient groups corresponding to WHO Stages I, II, and III, in each case relative to the resting value while lying down immediately preceding the activity.

Key: a. Morning
b. Noon
c. Evening
d. Stage

in the morning and at midday. This is consistent with clinical experience both with respect to the increased frequency of disturbed orthostatic regulation in the morning hours and with respect to the increase in such spontaneous reactions with the severity of the hypertonia.

The entire breadth of everyday variability of blood pressure in hypertensives is best demonstrated by a comparison of mean values for minimum blood pressure in sleep and of values obtained /1228 during stair climbing in the evening: these figures show that the mean systolic/diastolic blood pressure increment is 73.1/26.0

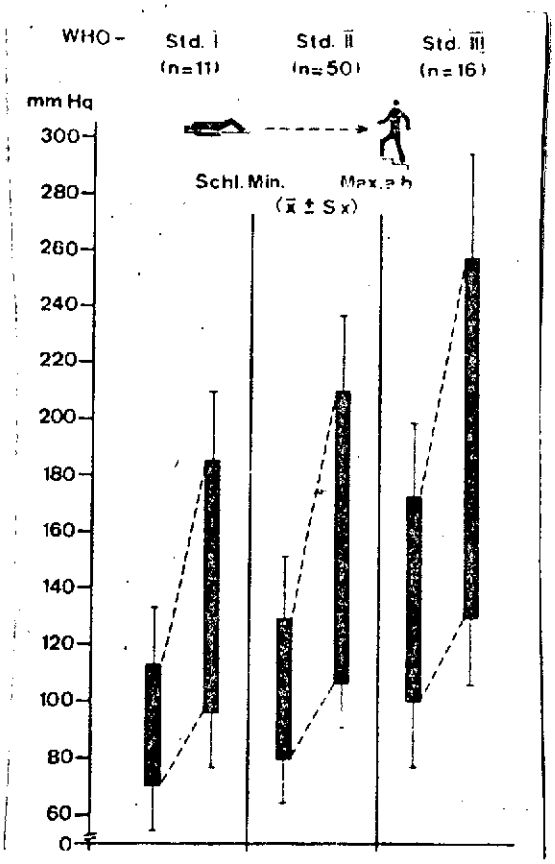

Fig. 5. Comparison of mean values (with standard deviations) of systolic and diastolic blood pressures of extreme values occurring under everyday conditions: minimum in sleep (Schl. Min.) and maximum during stair climbing in the evening (Max. ab.).

Key: Std. = stage

in patients of WHO Stage I, 80.8/27.2 in patients of WHO Stage II, and 85.2/29.3 mm Hg in patients of WHO Stage III. Nevertheless, in terms of percentages, the variability decreases with the severity of the hypertonia (Fig. 6).

As we showed in other studies (Krönig et al., 1974), knowing individual blood pressure reactions to everyday loads may have valuable therapeutic consequences for individual hypertensives: namely, while some antihypertensive drugs such as thiabutazide and spironolactone depress the everyday blood pressure profile rather uniformly, other substances such as α-methyl-Dopa, clonidine, reserpine, and guanethidine bring about preferential depression of blood pressure during exercise, i.e. they can inhibit the hypertensive reaction to stress more strongly than they can depress the resting blood pressure.

Conclusion and Summary

The method of microcatheter blood pressure telemetry makes it possible to gain deeper insight into spontaneous variability in

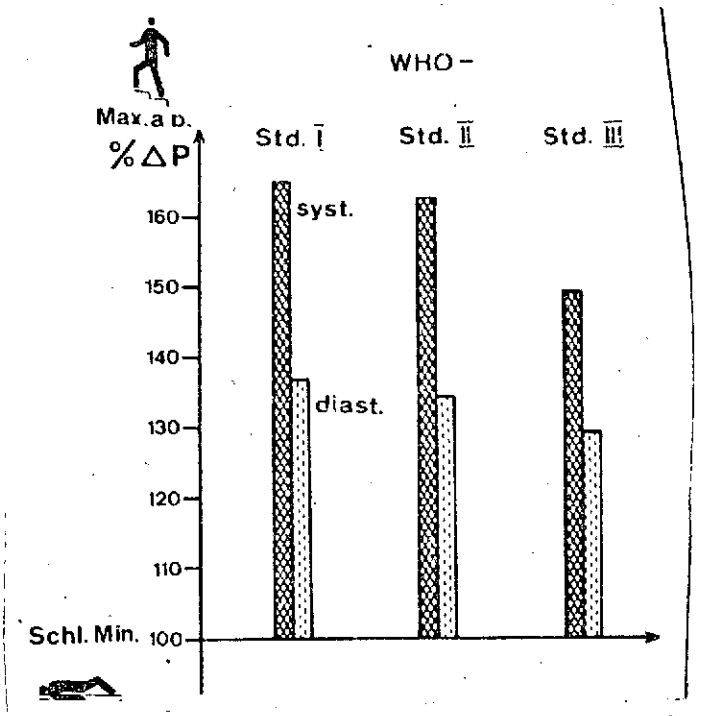

Fig. 6. Depiction of mean values as in Fig. 5, in percentage terms. Everyday variability of blood pressure decreases with increasing severity of hypertonia. [Max. ab. and Schl. Min. as in Fig. 5, Std. = stage].

everyday blood pressure levels. In long-term measurements on 77 unselected hypertensives, we detected the well-known circadian and diurnal rhythms of resting blood pressure for the three degrees of hypertonic severity differentiated by the WHO criteria, in roughly the same fashion but at various blood pressure levels. Ordinary exercise such as walking and stair climbing cause substantial modifications in the resting blood pressure profile, the systolic blood pressure increment being greater in the afternoon and evening than in the morning. An orthostatic drop in systolic blood pressure occurs more frequently in the morning hours, and preferentially in the patients of WHO Stages II and III. The dynamic character of ordinary blood pressure should be taken into account in the diagnosis and therapeutic treatment of hypertensives.

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